Experimental seasonal hydrologic forecasting for the Western U.S.

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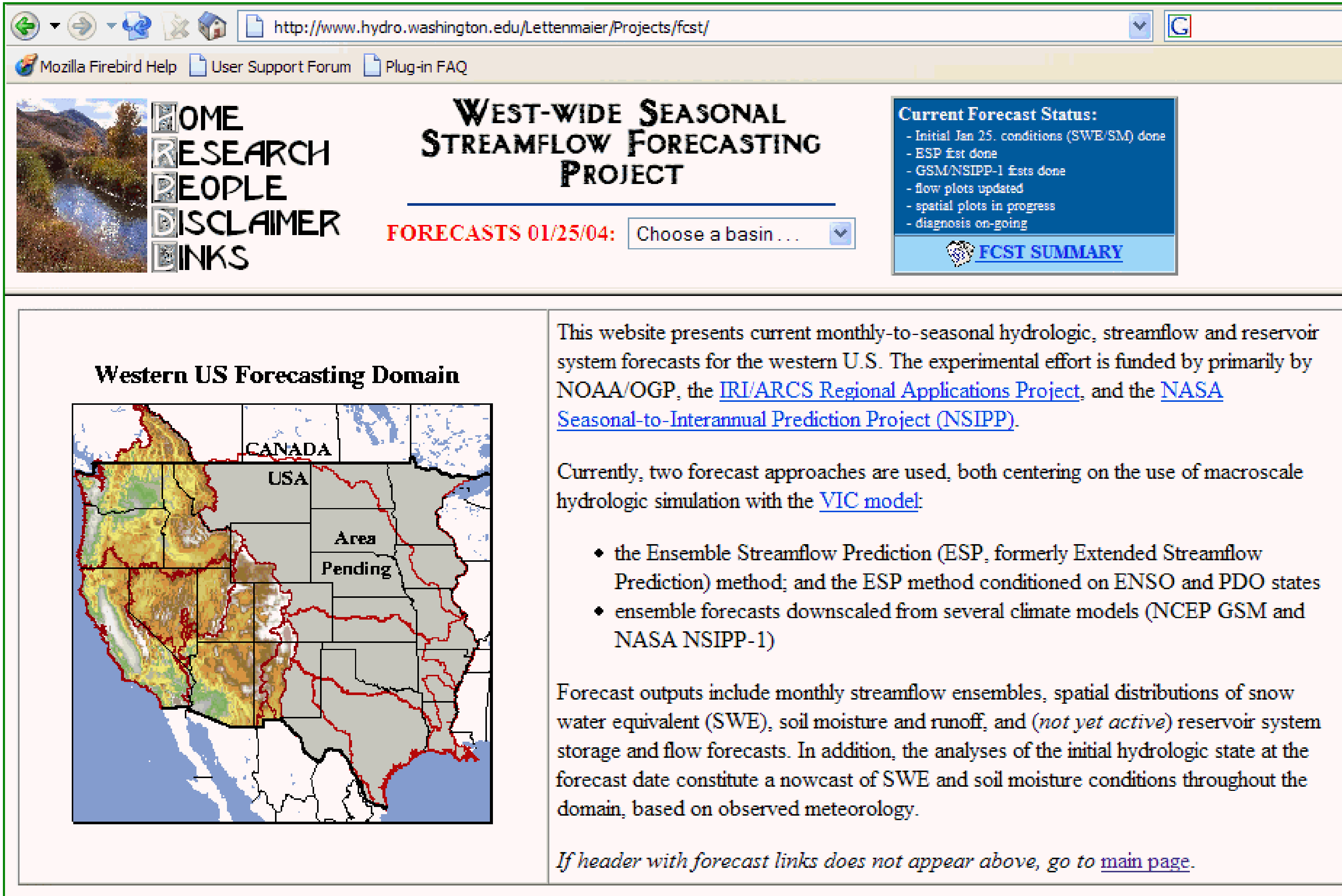
Outline

1. **Overview of current activities / Challenges**

2. **Conclusions**

Overview: Project Domain


http://www.hydro.washington.edu/Lettenmaier/Projects/fcst/

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WEST-WIDE SEASONAL STREAMFLOW FORECASTING PROJECT

FORECASTS 01/25/04: Choose a basin . . .

Current Forecast Status:
- Initial Jan 25. conditions (SWE/SM) done
- ESP fcst done
- GSM/NSIPP-1 fcsts done
- flow plots updated
- spatial plots in progress
- diagnosis on-going

FCST SUMMARY

Western US Forecasting Domain

CANADA
USA
Area Pending

This website presents current monthly-to-seasonal hydrologic, streamflow and reservoir system forecasts for the western U.S. The experimental effort is funded by primarily by NOAA/OGP, the IRI/ARCS Regional Applications Project, and the NASA Seasonal-to-Interannual Prediction Project (NSIPP).

Currently, two forecast approaches are used, both centering on the use of macroscale hydrologic simulation with the VIC model:

- the Ensemble Streamflow Prediction (ESP, formerly Extended Streamflow Prediction) method; and the ESP method conditioned on ENSO and PDO states
- ensemble forecasts downscaled from several climate models (NCEP GSM and NASA NSIPP-1)

Forecast outputs include monthly streamflow ensembles, spatial distributions of snow water equivalent (SWE), soil moisture and runoff, and (*not yet active*) reservoir system storage and flow forecasts. In addition, the analyses of the initial hydrologic state at the forecast date constitute a nowcast of SWE and soil moisture conditions throughout the domain, based on observed meteorology.

If header with forecast links does not appear above, go to main page.

Overview: Forecasting System Evolution

1998-9 Ohio R. basin w/ COE: *First tried climate model-based seasonal forecasts on experimental (retrospective) basis*

2000 Eastern US: *First attempted real-time seasonal forecasts during drought condition in southeastern states -- results published in: Wood et al. (2001), JGR*

2001 Columbia R. basin: *Implemented approach during the PNW drought, again using climate model based approach*

2002 Western US: *Retrospective analysis of forecasts over larger domain (for one climate model and for ESP)*

2003 Columbia R. basin: *New funding for "pseudo-operational" implementation for western US; began with pilot project in CRB*

(Funding from: NASA NSIPP; IRI/ARCS; NOAA GCIP/GAPP)

2004 Western US: *expanded to western U.S domain for real-time forecasts; working to improve and evaluate methods each forecast cycle*

Overview: UW Experimental West-wide hydrologic prediction system

Department of Civil and Environmental Engineering

climate model output (NCEP, NSIPP)

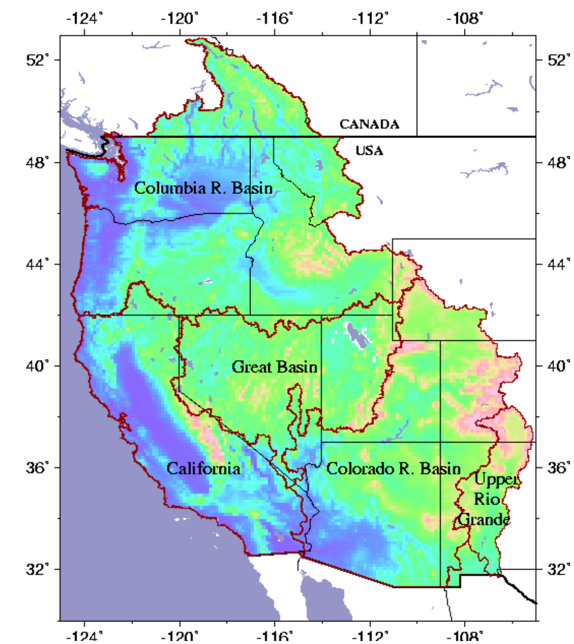
CPC official forecasts (in progress)

ESP as baseline fcst

Real-time Ensemble Forecasts

Ensemble Hindcasts (for bias-correction and preliminary skill assessment)

1. Downscaling
2. VIC hydrologic simulations



West-wide forecast products
- streamflow
- soil moisture, snowpack

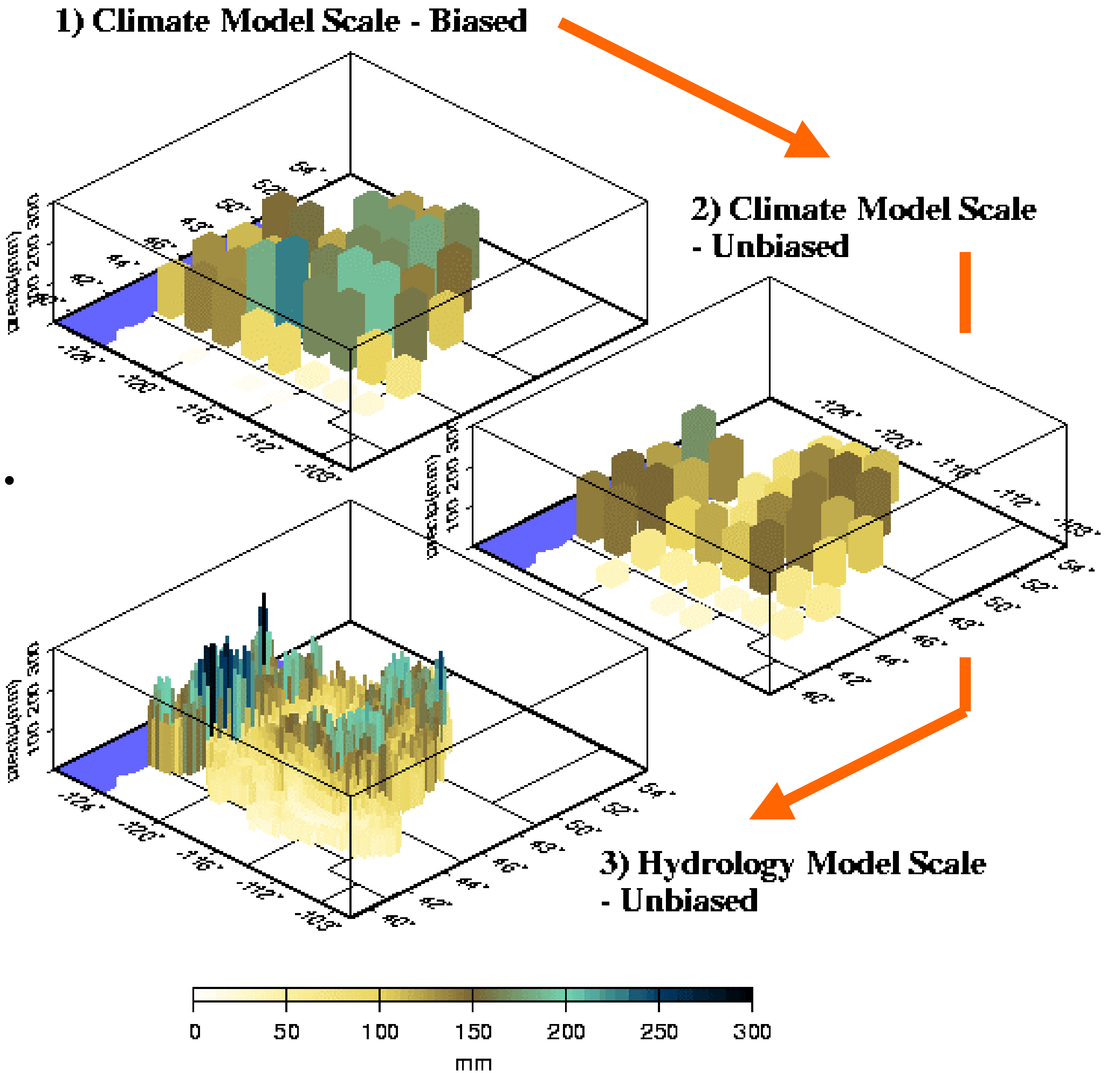
tailored to application sectors
- fire, power, recreation

*** ESP**
extended streamflow prediction (unconditional climate forecasts run from current hydrologic state)

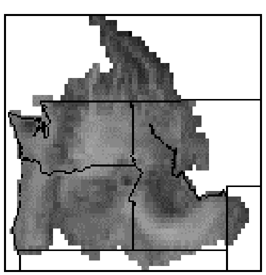
Challenge: Climate Model Forecast Use

bias-correcting…

then downscaling…

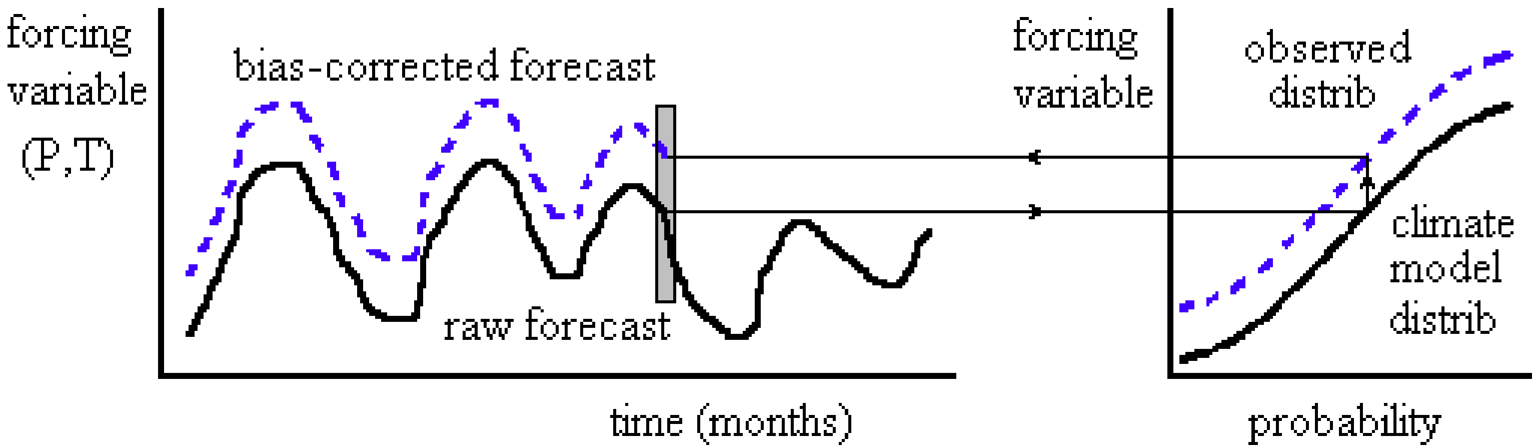


CRB domain, June precip



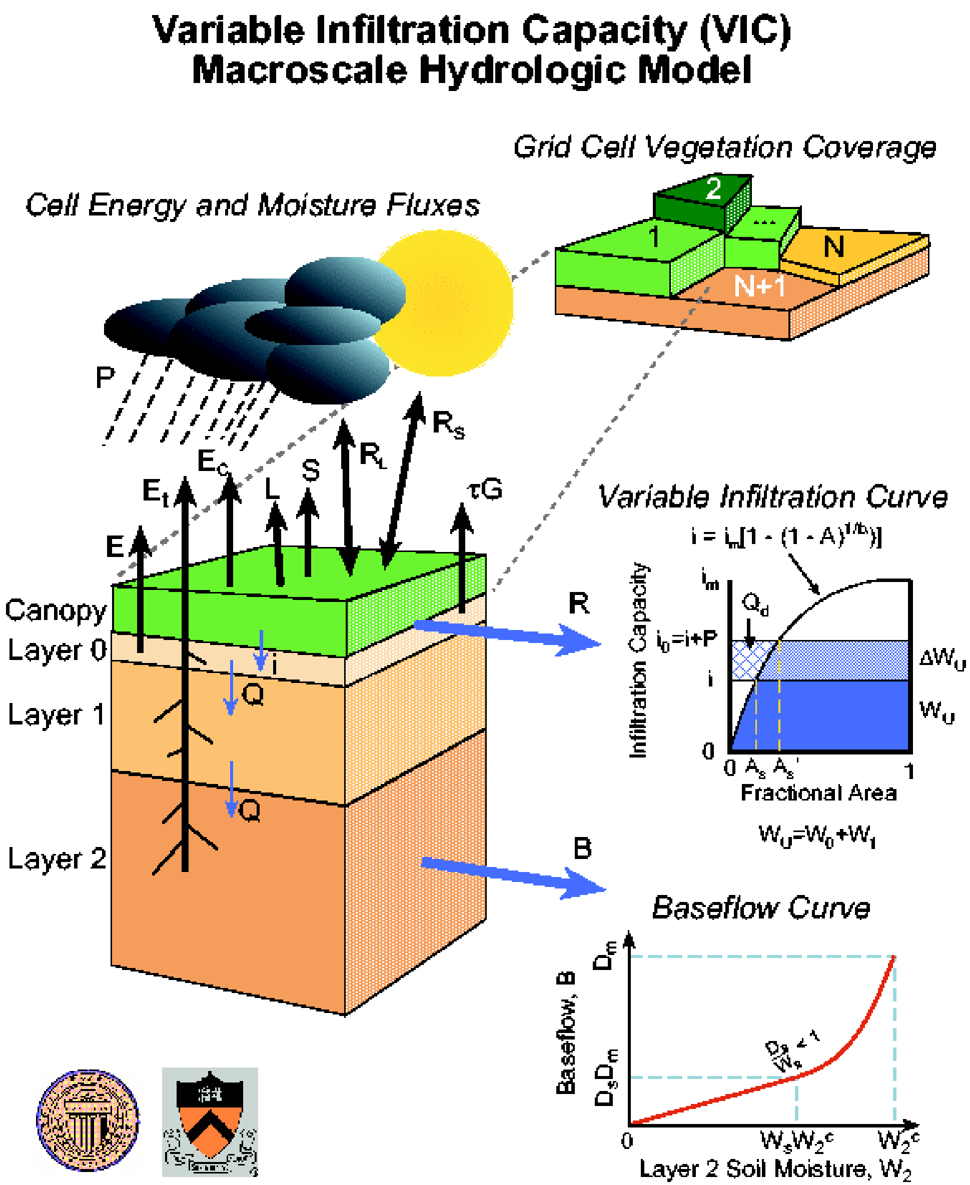
Overview: Bias Correction

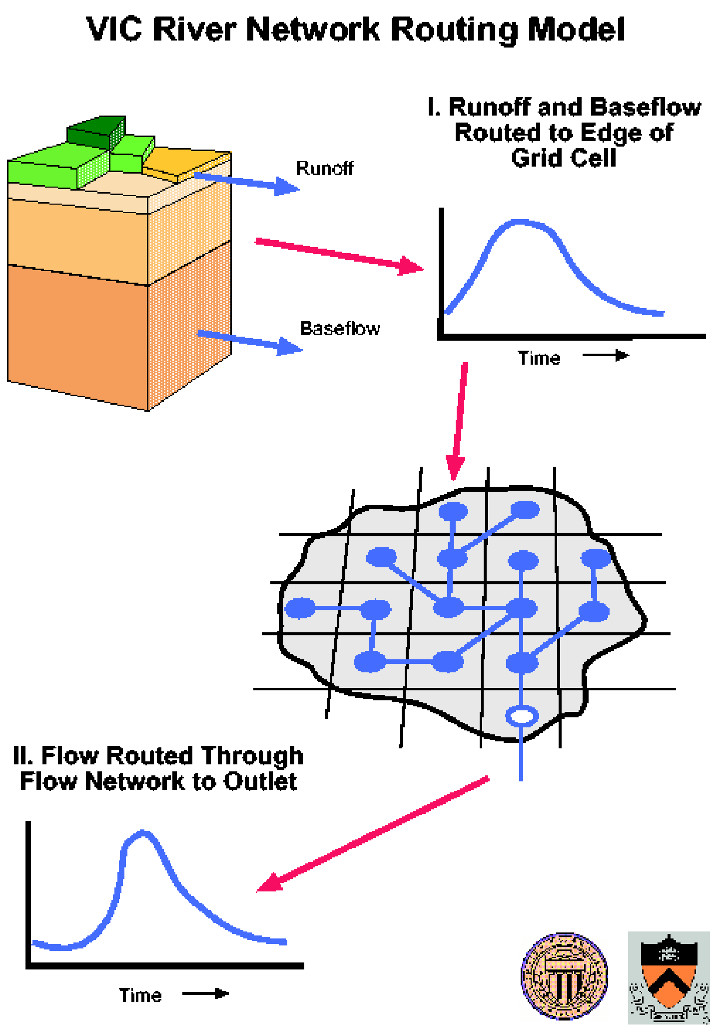
- numerous methods of downscaling and/or bias correction exist
- the relatively simple one we've settled on ***requires a sufficient retrospective climate model climatology, e.g.,***
  - NCEP: hindcast ensemble climatology, 21 years X 10 member
  - NSIPP-1: AMIP run climatology, > 50 years, 9 member



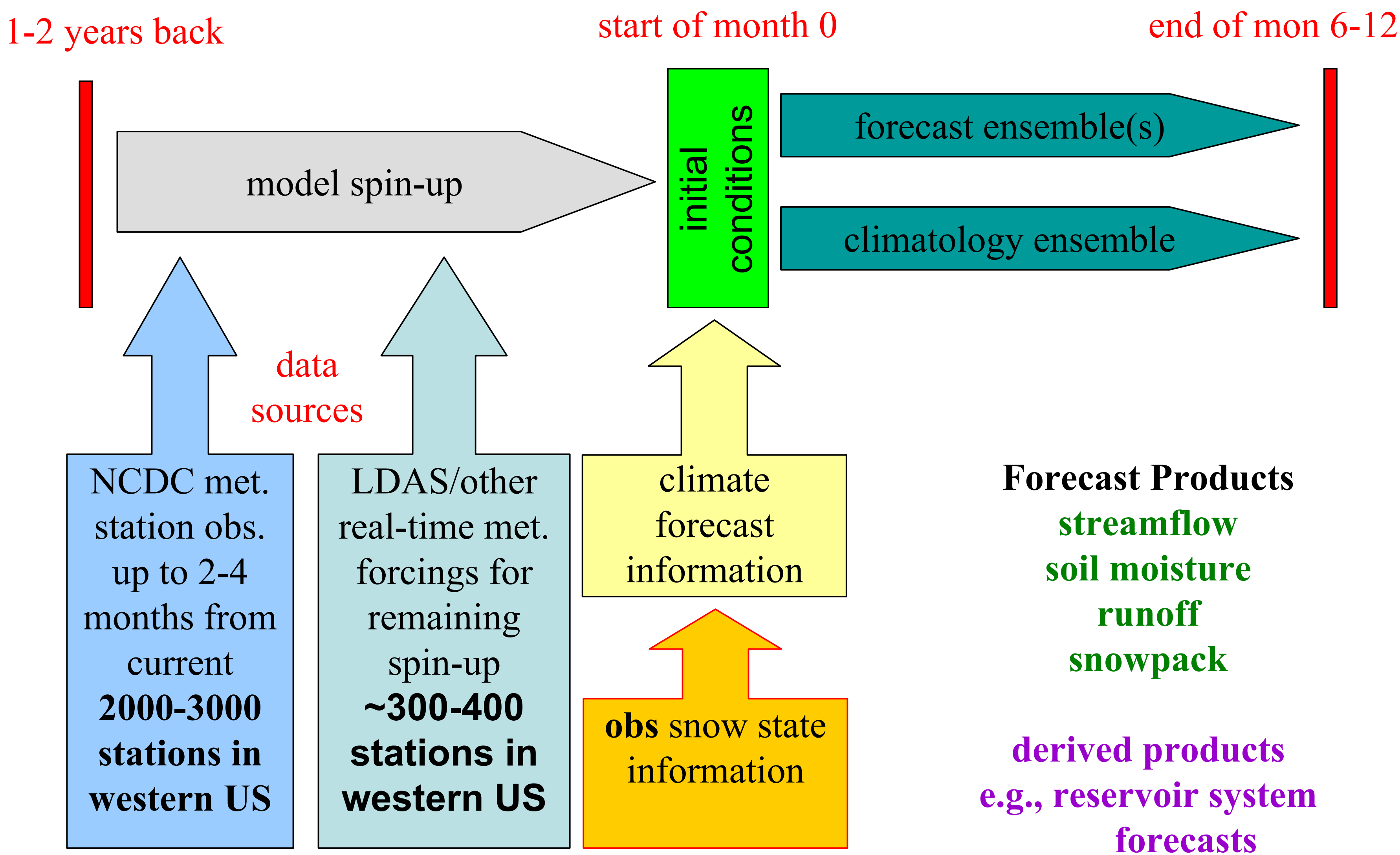
specific to calendar month and climate model grid cell

Overview: VIC Hydrologic Model





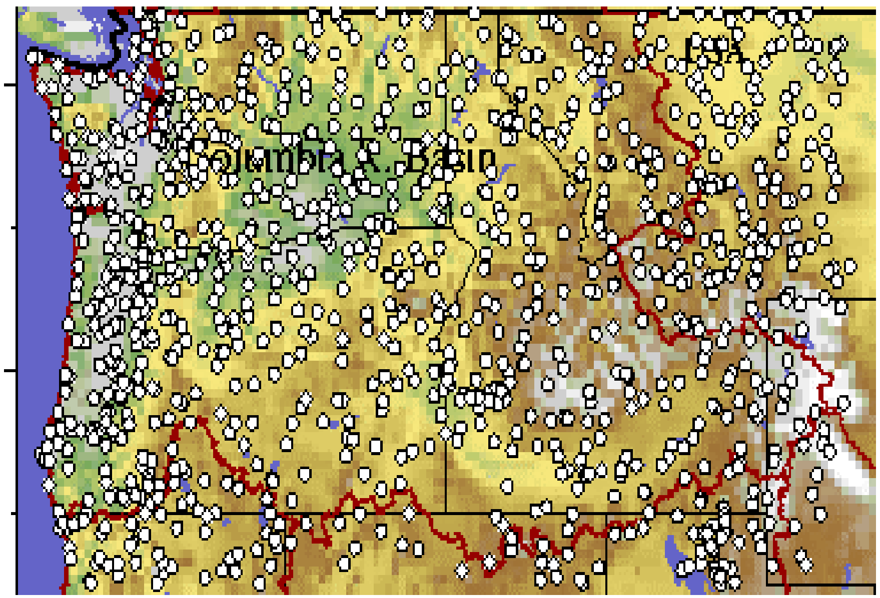
Overview: Hydrologic Simulations



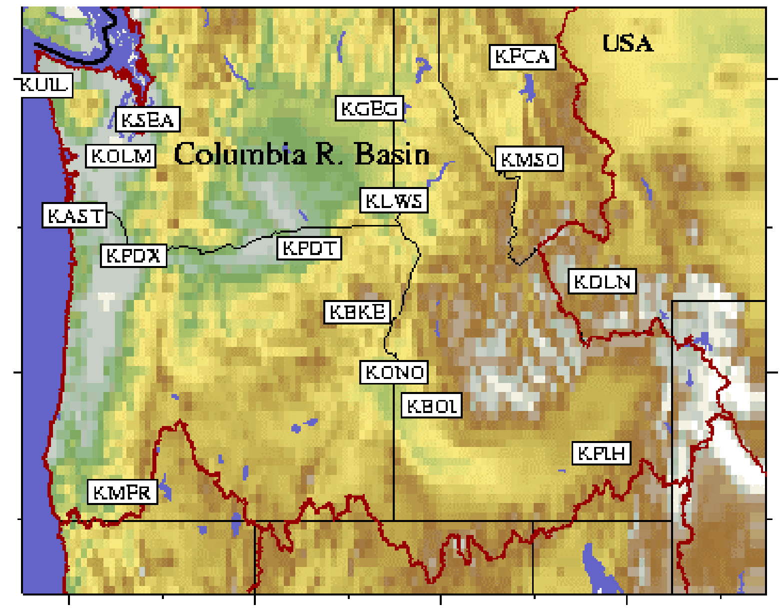
Challenge: Hydrologic State Initialization

Problem: met. data availability in 3 months prior to forecast has only a tenth of long term stations used to calibrate model

dense station network for model calibration

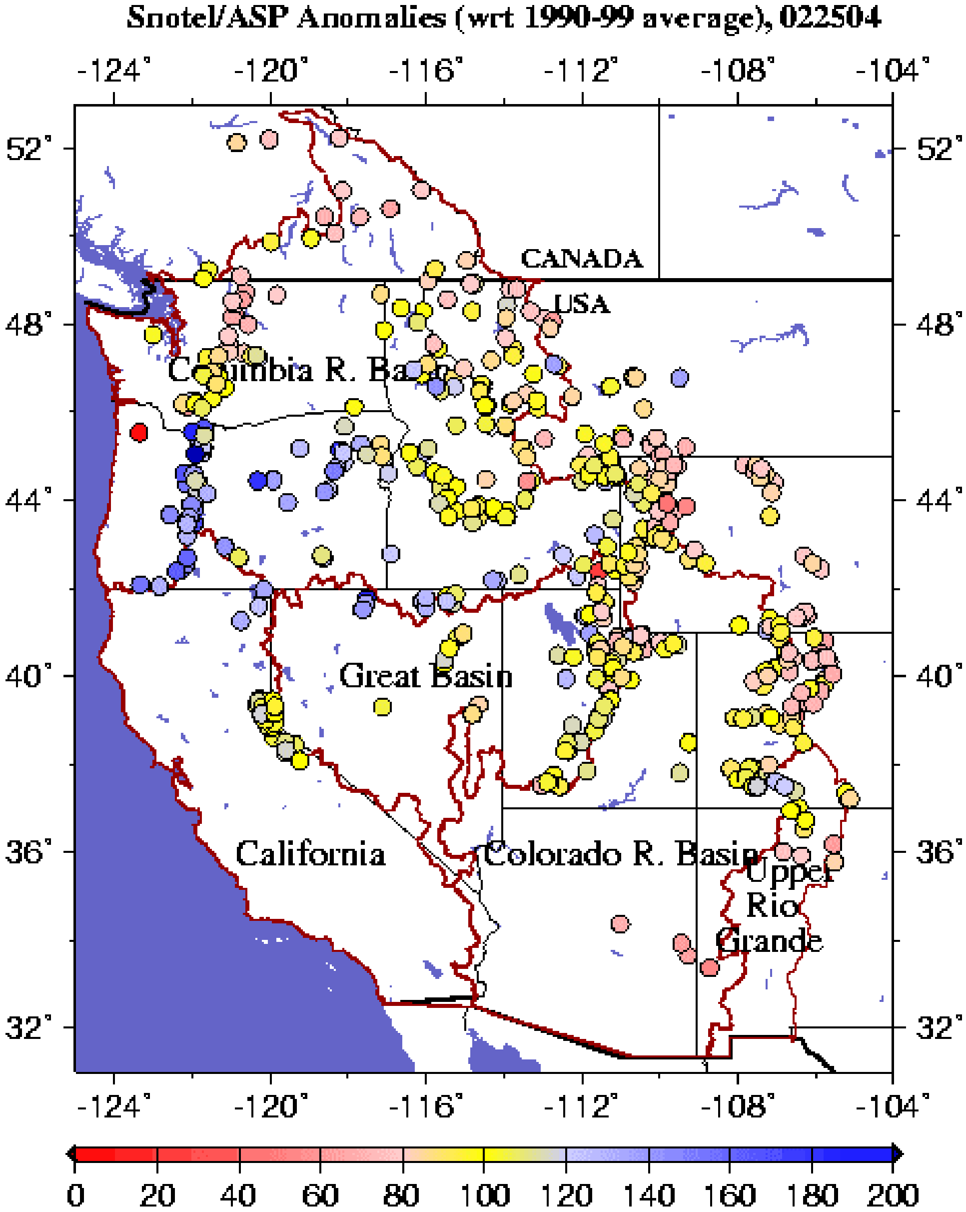


sparse station network in real-time



Solution: use interpolated monthly index station precip percentiles and temperature anomalies to extract values from higher quality retrospective forcing data, then disaggregate using daily index station signal.

Overview: Initial snow state assimilation



Problem

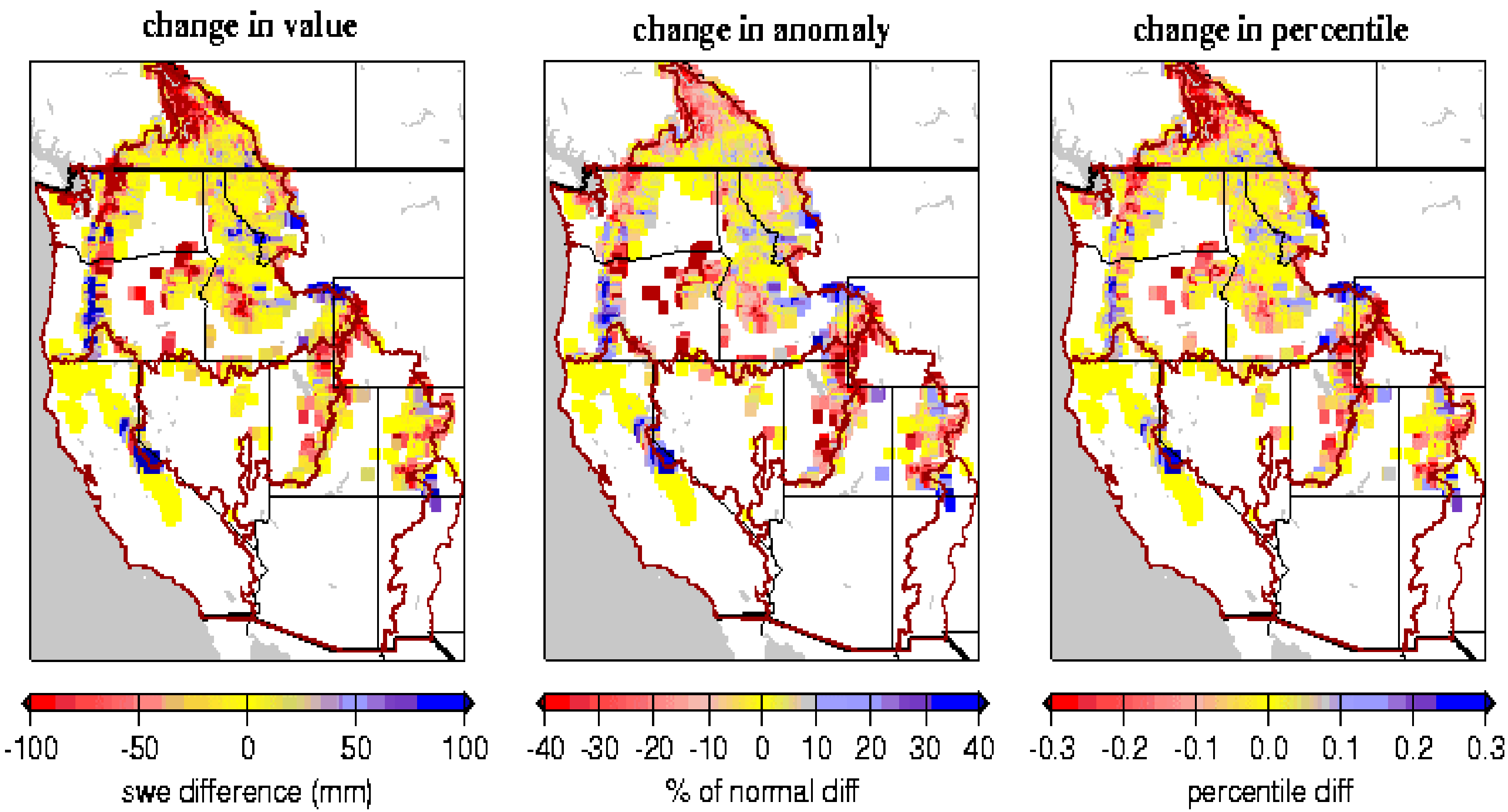
sparse station spin-up period incurs some systematic errors, but snow state estimation is critical

Solution

use SWE anomaly observations (from the 600+ station USDA/NRCS SNOTEL network and a dozen ASP stations in BC, Canada) to adjust snow state at the forecast start date

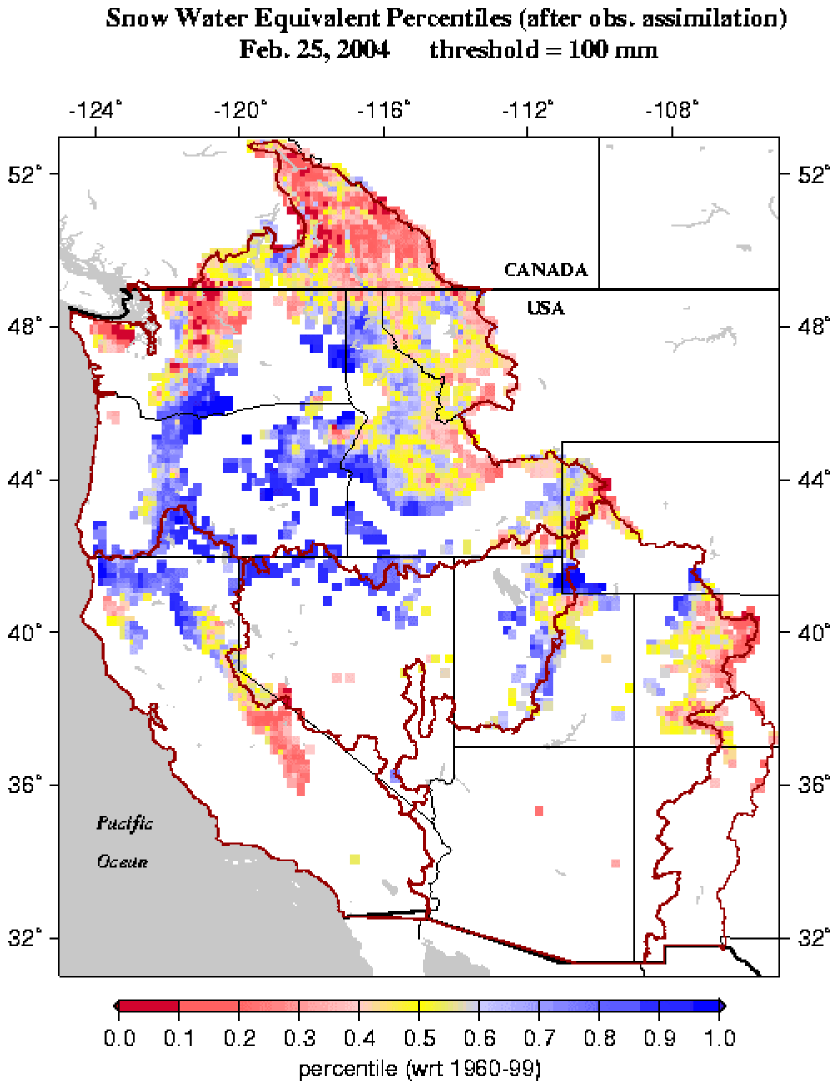
Overview: Initial snow state assimilation

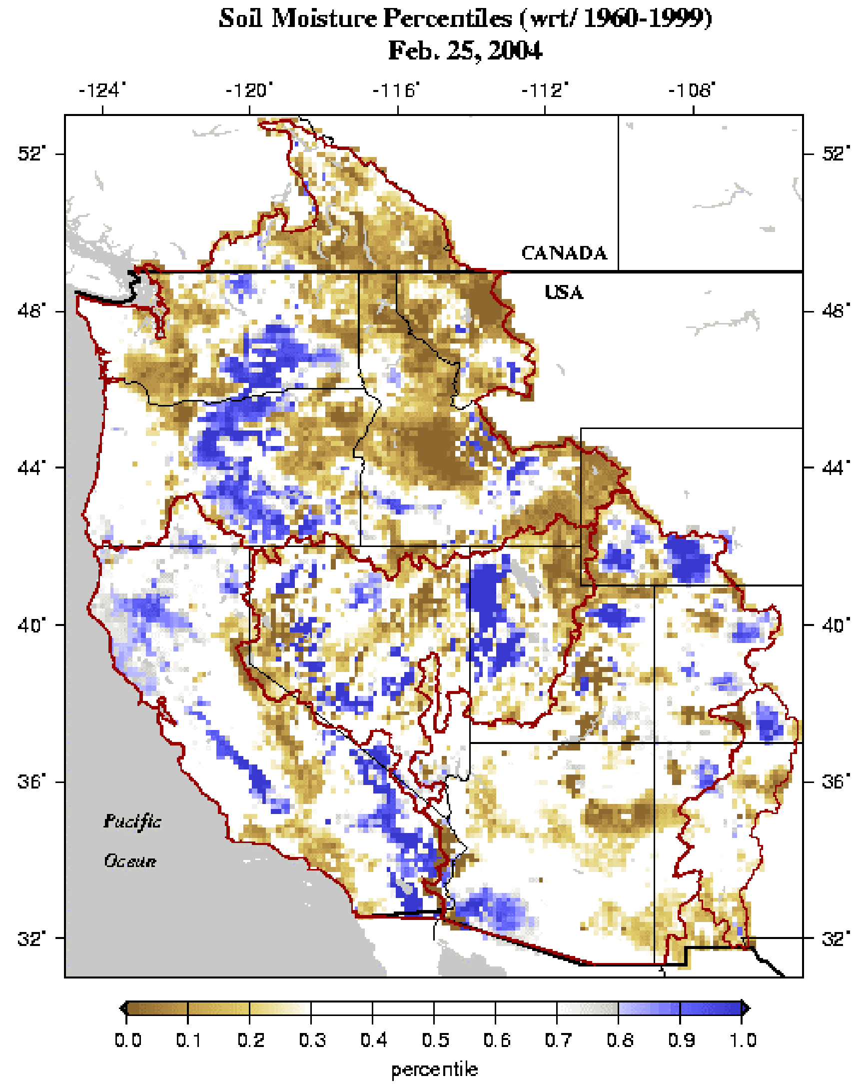
SWE state differences due to assimilation of SNOTEL/ASP observations, Feb. 25, 2004



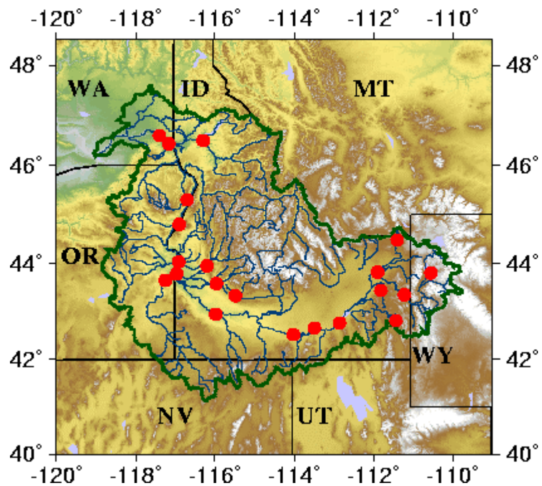
Overview: Initial conditions

Snow Water Equivalent (SWE) and Soil Moisture

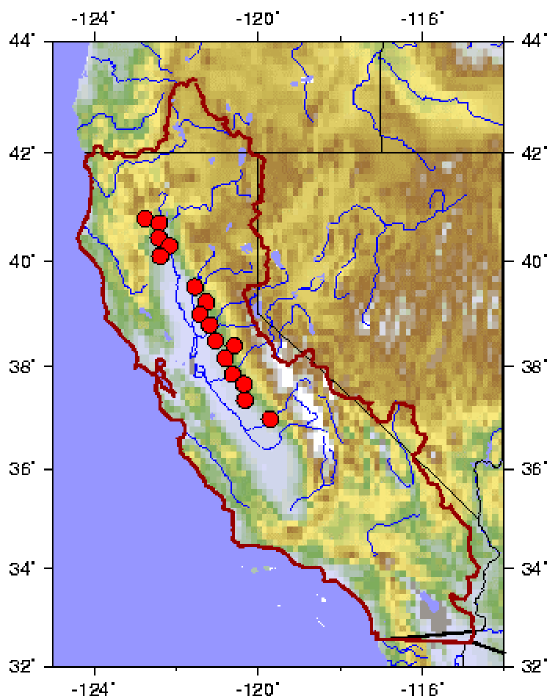




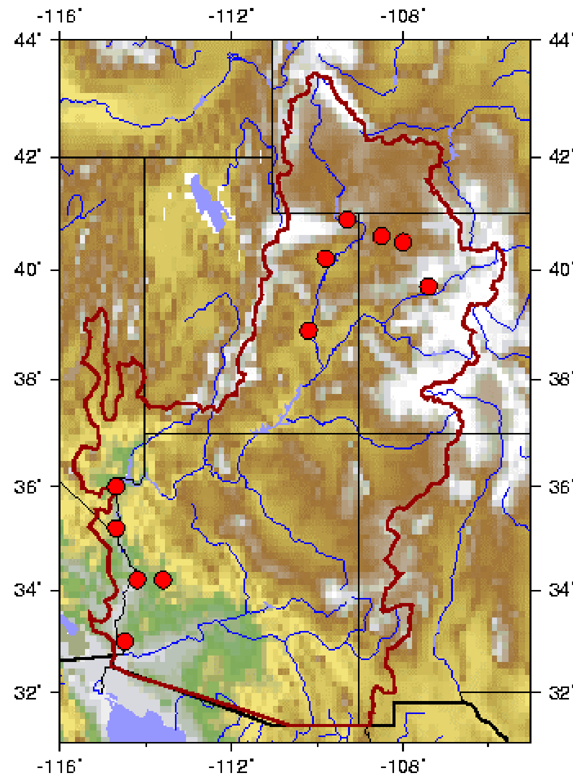
Overview: Streamflow Forecast Locations



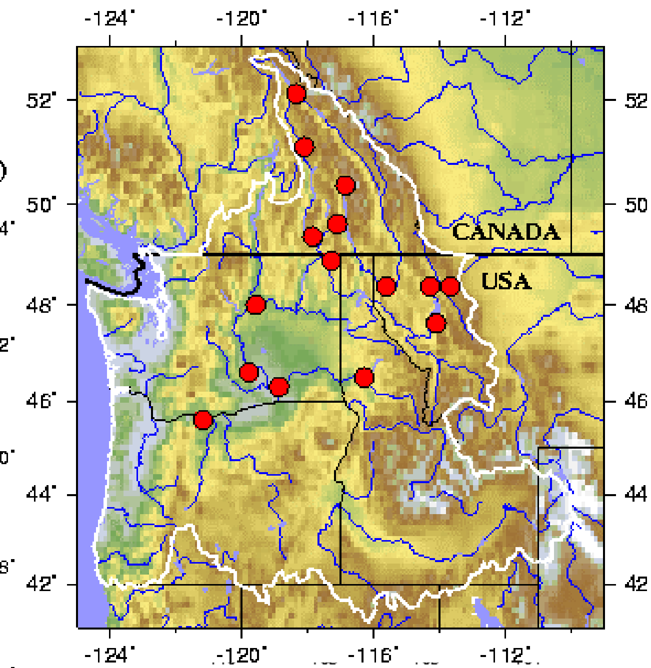
California Streamflow Forecast Points (clickable)

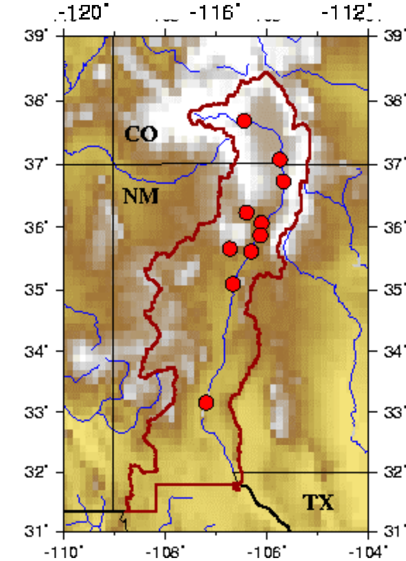


Colorado Streamflow Forecast Points (clickable)



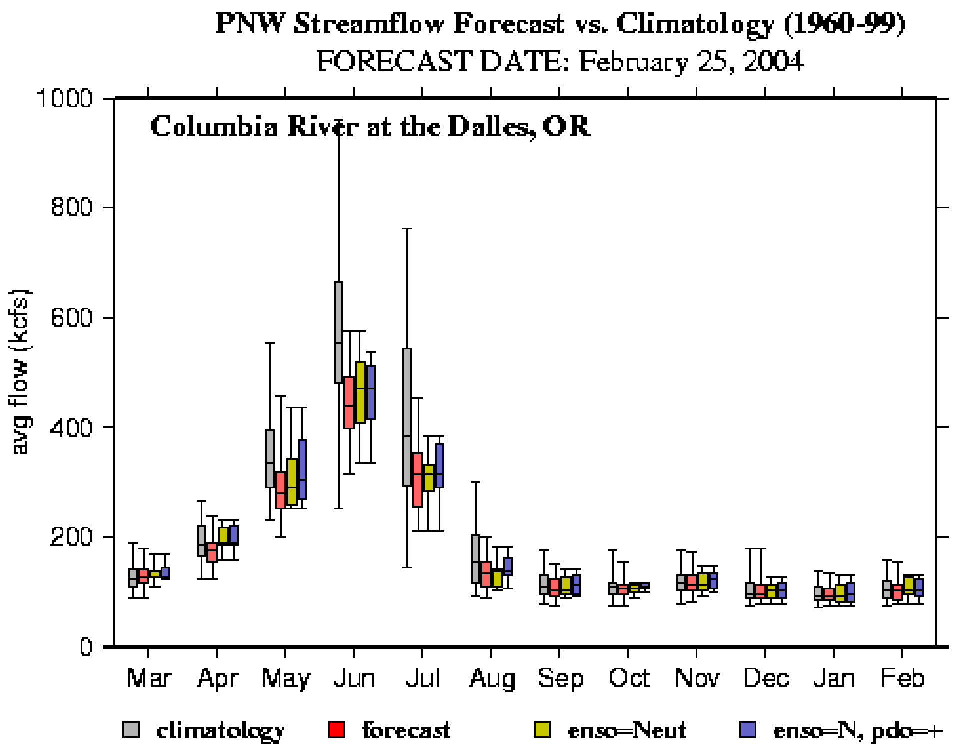
CRB Streamflow Forecast Points (clickable)





Overview: Streamflow Forecasts

hydrographs



targeted statistics

Forecast flow percent of average for 2004 APR-SEP averag
at low, median and high percentiles

#	NAME	----- unconditional ----- 0.1	0.5	0.9	ENSO-Neut 0.5
1	MICAA	73	85	97	85
2	REVEL	73	85	98	85
3	ARROW	72	83	97	84
4	DUNCA	68	84	100	85
5	LIBBY	62	76	92	86
6	CORRA	64	79	91	83
7	HHORS	59	74	94	77
8	COLFA	58	76	90	82
9	KERRR	59	77	92	85
10	WANET	67	80	95	85
11	CHIEF	71	81	93	84
12	PRIES	70	81	93	83
13	DWORS	62	72	89	80
14	ICEHA	60	75	88	74
15	DALLE	72	81	91	83

raw ensemble data

Mica Lake, BC

5722.9	6644.9	9046.8	19563.8	44792.6	38968.7	9883.4
5806.2	6125.6	8715.4	41331.7	63017.9	14724.0	9218.0
6021.7	5659.0	10163.9	23089.4	48808.7	32002.6	15635.5
6008.6	6178.3	9259.0	32229.8	46713.3	22615.6	12493.9
5775.0	5313.0	7008.2	14508.3	53318.3	51655.1	19877.6
5781.6	5663.2	9679.3	29579.9	61400.8	28590.8	12592.2

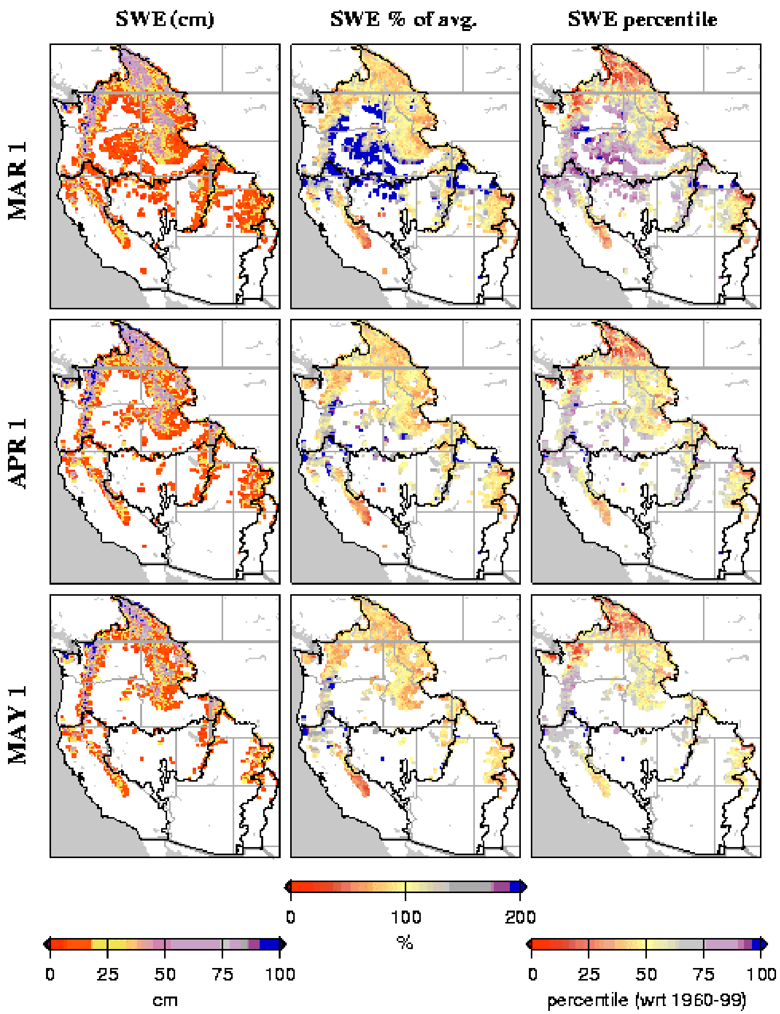
Overview:

Spatial Forecasts

monthly values, anomalies and percentiles of:
precip, temp, SWE, soil moisture, runoff
give streamflow forecasts greater context

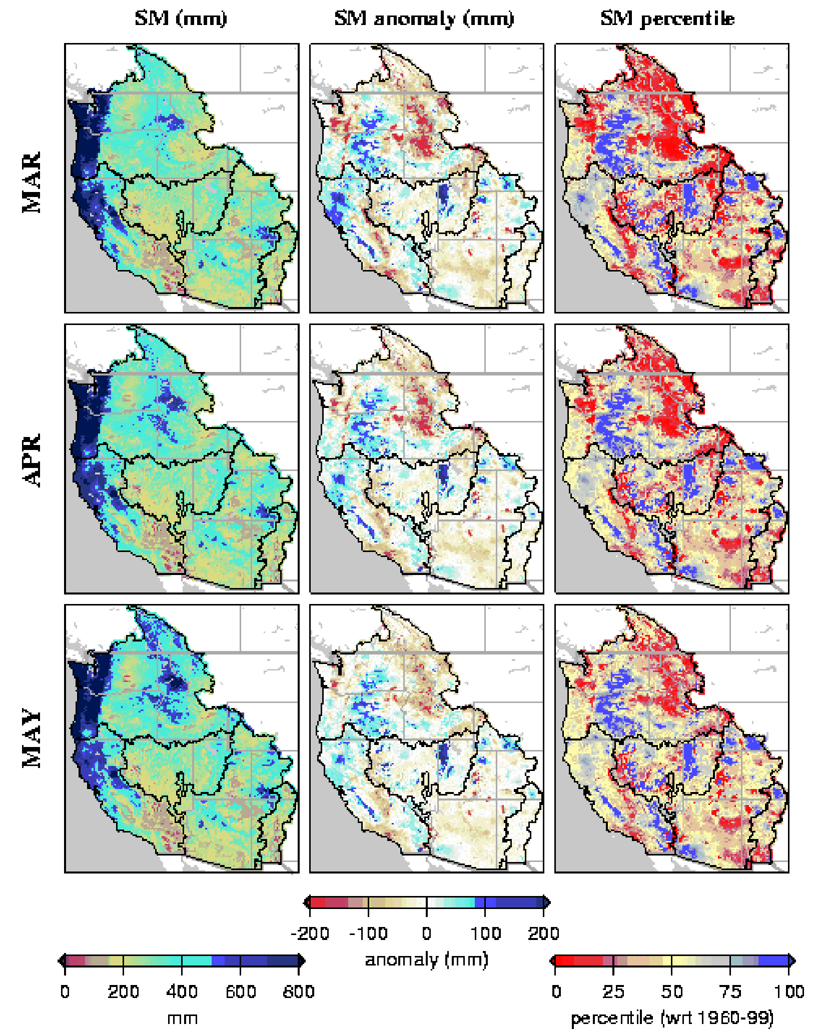
SWE

Snow Water Equivalent (SWE) Forecasts (Feb. 25, 2004)
(plot threshold: 50 mm SWE)

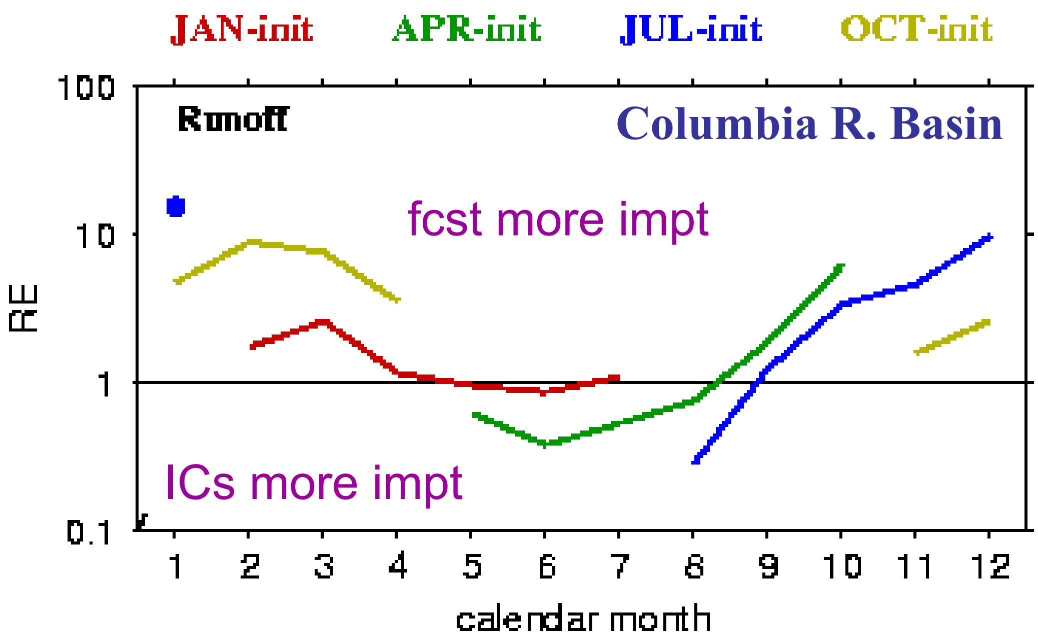


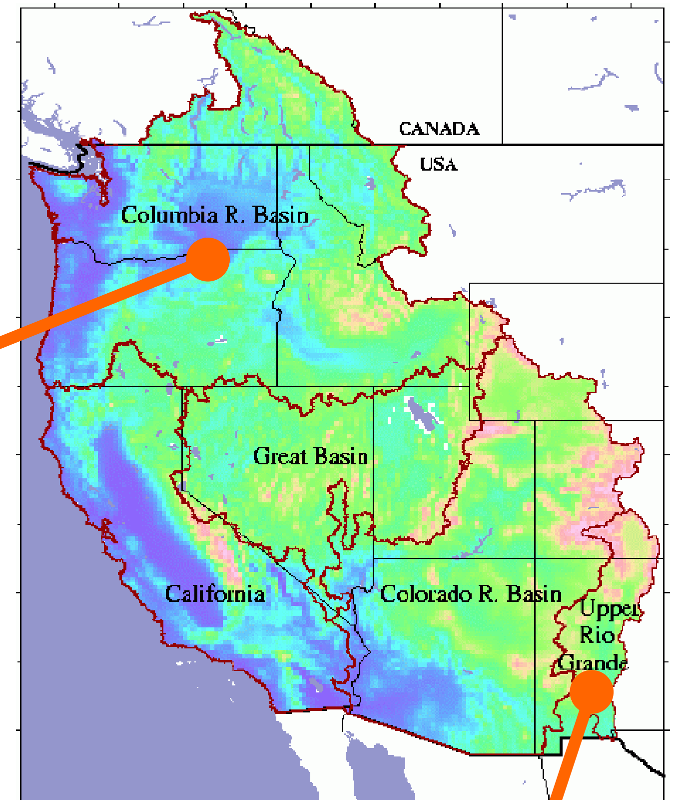
soil moisture

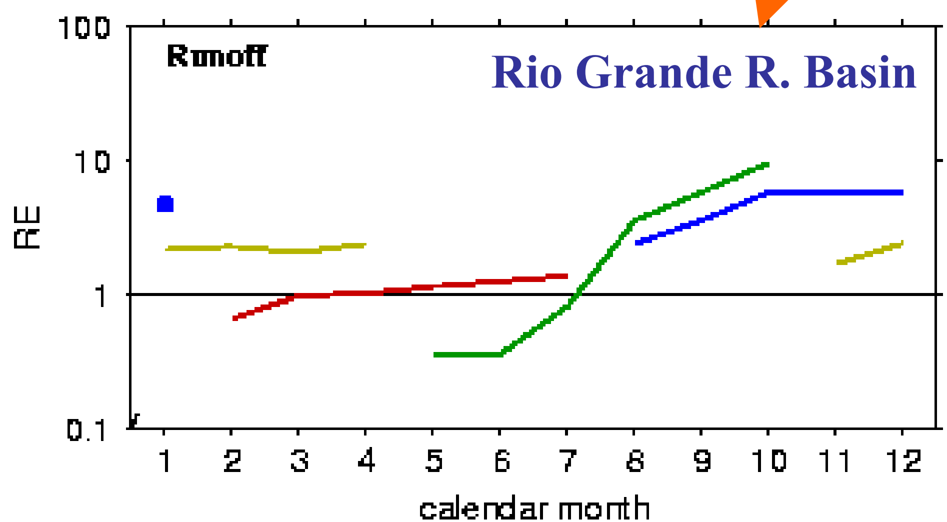
Soil Moisture (SM) Forecasts (Feb. 25, 2004)



Challenge: Balancing IC effort with forecast effort







$$\text{RE} = \frac{\text{RMSE (perfect IC, uncertain fcst)}}{\text{RMSE (perfect fcst, uncertain IC)}}$$

Conclusions

- **Modern hydrologic methods can readily provide seasonal forecast results comparable to those in current operational use, and have great potential to do better.**

- **Bias issues in climate models must be addressed – good retrospective model climatologies are essential.**

- **Forecasting would benefit greatly from an increased availability of real-time weather observations (esp., longer record & higher elevation stns).**

- **An understanding of the relative importance of hydrologic ICs and climate forecasts is helpful for setting system development priorities.**

- **retrospective forecast assessment must be possible to establish track record (problem for CPC, LDAS use w/ seasonal forecasts).**

www.hydro.washington.edu/Lettenmaier/Projects/fcst/